Listing of Claims

Please replace all prior versions of claims with the following listing of claims:

1. (*Currently Amended*)   A lithographic apparatus comprising:

a support structure configured to hold a patterning structure, the patterning structure being configured to pattern a beam of radiation according to a desired pattern;

a substrate table configured to hold a substrate including an alignment structure having spatially periodic optical properties; and

an alignment subsystem configured to align the substrate relative to the patterning structure, the alignment subsystem comprising:

optics configured to process light affected by the alignment structure and to produce measurement light whose intensity varies with a position of the spatially periodic alignment structure relative to a reference position relating to a position of the patterning structure; and

a sensor configured to measure at least one among intensity information of the measurement light and phase information of the measurement light,

wherein the alignment subsystem is further arranged to determine a position of a non-periodic feature of the alignment structure and wherein the non-periodic feature comprises a transition from a first part of the alignment structure having a first periodicity to a second part of the alignment structure having a second periodicity.

2. (*Original*)   The lithographic apparatus according to claim 1, said apparatus further comprising an actuator configured to control a relative position of the substrate table and the patterning structure based on the measured information of the measurement light.

3. (*Original*)   The lithographic apparatus according to claim 1, wherein the optics includes an optical interference arrangement.

4. (*Original*)   The lithographic apparatus according to claim 1, wherein the patterning structure is configured to impart the beam with a pattern in its cross-section.

5. (*Original*)   The lithographic apparatus according to claim 1, wherein the alignment subsystem is arranged to determine the position from a phase shift induced by the non-periodic feature.

6. (*Original*)   The lithographic apparatus according to claim 5, wherein the non-periodic feature includes at least one of a change of the width of one of the lines of the alignment structure and a change of the width of one of the spaces of the alignment structure.

7. (*Currently Amended*)   The lithographic apparatus according to claim 5, wherein the optics comprises a reference grating, and

~~wherein the non-periodic feature comprises a transition from a first part of the alignment structure having a first periodicity to a second part of the alignment structure having a second periodicity, and~~

wherein the first periodicity is less than the periodicity of the reference grating, and wherein the second periodicity is greater than the periodicity of the reference grating.

8. (*Original*)   The lithographic apparatus according to claim 7, wherein the alignment subsystem is arranged to determine the position from sloped phase information of the measurement light.

9. (*Original*)   The lithographic apparatus according to claim 5, wherein the alignment structure comprises a position-dependent period change expressible as

$$\Delta(x) = \frac{\cos\left(\frac{2\pi}{L} x\right) - 1}{x}$$

wherein $\Delta(x)$ denotes the position-dependent period change, x denotes a position along the alignment structure, and L denotes a length of the alignment structure over which the phase varies.

10. *(Original)* The lithographic apparatus according to claim 9, wherein the alignment subsystem is arranged to determine the position from sinusoidal-shaped phase information of the measurement light.

11. *(Original)* The lithographic apparatus according to claim 1, wherein the alignment subsystem is arranged to determine the position from a spatial dependence of the intensity information of the measurement light.

12. *(Original)* The lithographic apparatus according to claim 11, wherein the non-periodic feature comprises the finite dimension of the alignment structure, and

wherein the alignment subsystem is arranged to determine the position from an envelope of the intensity of the measurement light.

13. *(Original)* The lithographic apparatus according to claim 12, wherein the alignment structure has a first dimension in a first direction and a second dimension in a second direction, the second direction being substantially perpendicular to the first direction, and

wherein the non-periodic feature is one of the first and second dimensions, and

wherein the alignment subsystem is arranged to determine the position from an envelope of the intensity of the measurement light.

14. *(Currently Amended)* The lithographic apparatus according to claim 11, wherein ~~the non-periodic feature includes a transition from a first part of the alignment structure to a second part of the alignment structure,~~ the first part of the alignment structure has ~~having~~ a periodicity of X μm and the second part of the alignment structure has ~~having~~ a periodicity of X/n μm,

wherein X is a positive nonzero number and n is a positive nonzero integer.

15. *(Original)* The lithographic apparatus according to claim 14, wherein the alignment subsystem is arranged to determine the position from a change in the intensity of an n-th order of diffraction of the measurement light.

16. (*Currently Amended*)   The lithographic apparatus according to claim 11, wherein ~~the non-periodic feature includes a transition from a first part of the alignment structure to a second part of the alignment structure,~~ the first part of the alignment structure has ~~having~~ a first duty cycle value of the lines and spaces and the second part of the alignment structure has ~~having~~ a second duty cycle value of the lines and spaces.

17. (*Original*)   The lithographic apparatus according to claim 16, wherein the alignment subsystem is arranged to determine the position from a change in intensity of the measurement light.

18. (*Currently Amended*)   A lithographic apparatus comprising:

a support structure configured to hold a patterning structure, the patterning structure being configured to pattern a beam of radiation according to a desired pattern;

a substrate table configured to hold a substrate including an alignment structure having spatially periodic optical properties; and

an alignment subsystem configured to align the substrate relative to the patterning structure, the alignment subsystem comprising:

optics configured to process light affected by the alignment structure and to produce measurement light whose intensity varies with a position of the spatially periodic alignment structure relative to a reference position relating to a position of the patterning structure;

a sensor configured to measure at least one among intensity information of the measurement light and phase information of the measurement light.

~~The lithographic apparatus according to claim 1, in which the alignment subsystem further comprises:~~

a phase detector configured to determine a phase from the measured intensity information;

an amplitude detector configured to determine information regarding amplitudes of periodic variations of intensity of the measurement light as a function of the relative position of the substrate table and the patterning structure; and

a comparator configured to search for a relative position at which a corresponding amplitude is a maximum,

wherein the alignment subsystem is further arranged to determine a position of a non-periodic feature of the alignment structure and wherein the phase detector is arranged to determine a̶the phase from measurements of intensity information measured at a̶t least at one relative position that is selected based on the determined position.

19. *(Original)* The lithographic apparatus according to claim 18, wherein the information about different amplitudes is obtained over a range of relative positions that extends over more than a size of the alignment structure.

20. *(Original)* The lithographic apparatus according to claim 18, wherein the amplitude detector comprises a frequency selective filter arranged to form a filtered signal from the intensity information determined as a function of position, selectively passing position dependent variations of the intensity information with a spatial frequency corresponding to the alignment structure, the amplitude detector determining the information about the amplitude from the filtered signal.

21. *(Original)* The lithographic apparatus according to claim 18, wherein the actuator is arranged to use the phase to control one direction of the relative position, the direction corresponding to a spatial direction along which the optical properties of the alignment structure vary periodically, said range of relative positions among which the amplitude is maximized being distributed in two directions on the substrate.

22. *(Original)* The lithographic apparatus according to claim 18, wherein the actuator is arranged to use the phase to control one direction of the relative position, the one direction corresponding to a direction along which the optical properties of the alignment structure vary periodically, said range of relative positions among which the amplitude is maximized being distributed in a single further direction transverse to said direction.

23. *(Original)*   The lithographic apparatus according to claim 18, wherein the actuator is arranged to use the phase to control a first direction of the relative position, the actuator being arranged to control a second direction of the relative position using a further phase determined from a phase grating alignment measurement using a further alignment structure having optical properties that vary spatially periodically along the second direction, and

wherein the amplitude detector is arranged to determine information about amplitudes of periodic variations of the intensity of measurement light from the spatially periodical alignment structure and the further alignment structure as a function of the relative position of the substrate table and the patterning structure in directions transverse to the first and second direction respectively, and

wherein said comparator is arranged to search for a position that maximizes the amplitudes determined for the spatially periodical alignment structure and the further alignment structure in the directions transverse to the first and second direction respectively.

24. *(Original)*   The lithographic apparatus according to claim 18, wherein said comparator includes a processor.

25. *(Currently Amended)*   The lithographic apparatus according to claim 1, wherein the optics isare arranged to measure selectively the intensity information of measurement light diffracted by the alignment structure in directions corresponding to a pair of opposite non-zero orders of diffraction.

26. *(Currently Amended)*   The lithographic apparatus according to claim 1, wherein the optics comprises
a reference structure with spatially periodically varying optical properties; and
an imaging element configured to create an imaging relationship between the substrate and the reference structure, the reference structure having a period that corresponds to the period of the alignment structure when imaged onto the reference structure, the sensor configured to measure intensity information of measurement light that has been affected by both the reference structure and the alignment structure.

27.   (*Currently Amended*)   A device manufacturing method comprising:

using a patterning structure to pattern a beam of radiation according to a desired pattern; and

aligning a substrate, including an alignment structure having spatially varying optical properties, relative to the patterning structure, said aligning comprising:

processing light affected by the alignment structure to produce measurement light of which the intensity varies with the relative position of (1) the spatially periodic alignment structure and (2) a reference position relating to the patterning structure;

measuring at least one of intensity information and phase information of the measurement light; and

controlling a relative position of the substrate and the patterning structure based on the measured information,

wherein aligning a substrate includes detecting a position of a non-periodic feature of the alignment structure <u>and wherein the non-periodic feature comprises a transition from a first part of the alignment structure having a first periodicity to a second part of the alignment structure having a second periodicity</u>.

28.   (*Original*)   The device manufacturing method according to claim 27, said method further comprising projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material.

29.   (*Original*)   The device manufacturing method according to claim 27, wherein said measuring includes measuring phase information of the measurement light and detecting a phase shift induced by the non-periodic feature in the measured phase information.

30.   (*Original*)   The device manufacturing method according to claim 29, wherein the phase shift is induced by at least one of a change of the width of one of the lines and a change in width of one of the spaces of the alignment structure.

31. (*Currently Amended*)   The device manufacturing method according to claim 29, wherein the optics comprises a reference grating, and

~~wherein the non-periodic feature comprises a transition from a first part of the alignment structure having a first periodicity to a second part of the alignment structure having a second periodicity,~~

wherein the first periodicity is less than the periodicity of the reference grating and the second periodicity is greater than the periodicity of the reference grating.

32. (*Original*)   The device manufacturing method according to claim 31, wherein the position is detected using sloped phase information of the measurement light.

33. (*Original*)   The device manufacturing method according to claim 29, wherein the alignment structure comprises a position-dependent period change expressible as

$$\Delta(x) = \frac{\cos\left(\frac{2\pi}{L}x\right) - 1}{x}$$

wherein $\Delta(x)$ denotes the position-dependent period change, x denotes a position along the alignment structure, and L denotes a length of the alignment structure over which the phase varies.

34. (*Original*)   The device manufacturing method according to claim 33, wherein the position is detected using sinusoidal shaped phase information of the measurement light.

35. (*Original*)   The device manufacturing method according to claim 27, in which detecting a position includes detecting a spatial dependence of the intensity in the detected intensity information of the measurement light.

36. (*Original*)   The device manufacturing method according to claim 35, wherein the non-periodic feature comprises the finite dimension of the alignment structure, and

wherein the position is detected using an envelope of the intensity of the measurement light.

37.   (*Original*)   The device manufacturing method according to claim 36, wherein the alignment structure has a first dimension in a first direction and a second dimension in a second direction, the second direction being substantially perpendicular to the first direction, and

wherein the non-periodic feature is one of the first and second dimensions of the alignment structure.

38.   (*Currently Amended*)   The device manufacturing method according to claim 35, ~~wherein the non-periodic feature comprises a transition from a first part of the alignment structure to a second part of the alignment structure,~~

wherein the first part of the alignment structure has a periodicity of X microns, X being a positive nonzero number, and the second part of the alignment structure has a periodicity of X/n microns, n being a positive nonzero integer.

39.   (*Original*)   The device manufacturing method according to claim 38, wherein the position is detected using a change in the intensity of an n-th order of diffraction of the measurement light.

40.   (*Currently Amended*)   The device manufacturing method according to claim 35, ~~wherein the non-periodic feature comprises a transition from a first part of the alignment structure to a second part of the alignment structure,~~

wherein the first part of the alignment structure has a first duty cycle value of the lines and spaces and the second part of the alignment structure has a second duty cycle value of the lines and spaces.

41.   (*Original*)   The device manufacturing method according to claim 40, wherein the position is detected using a change in the intensity of the measurement light.

42.   (*Currently Amended*)   A device manufacturing method comprising:

using a patterning structure to pattern a beam of radiation according to a desired pattern; and

aligning a substrate, including an alignment structure having spatially varying optical properties, relative to the patterning structure, said aligning comprising:

processing light affected by the alignment structure to produce measurement light of which the intensity varies with the relative position of (1) the spatially periodic alignment structure and (2) a reference position relating to the patterning structure;

measuring at least one of intensity information and phase information of the measurement light; and

controlling a relative position of the substrate and the patterning structure based on the measured information,

~~The device manufacturing method according to claim 27, said method further comprising:~~

sensing intensities of the measurement light for successive relative positions including relative positions at which mutually non-overlapping available areas on the substrate contribute to the measurement light;

determining information about amplitudes of periodic variations of intensity of the measurement light;

searching for an optimal relative position that maximizes said amplitude information among the available areas; and

using the optimal relative position to select a measurement area from which the measurement light is used to determine the phase,

wherein aligning a substrate includes detecting a position of a non-periodic feature of the alignment structure.

43.   (*Original*)   The device manufacturing method according to claim 42, said method further comprising:

filtering the intensity information determined as a function of position with a frequency selective filter that selectively passes position dependent variations of the intensity information with a frequency corresponding to the alignment structure, and

determining the information about the amplitude from the filtered signal.

44.   (*Original*)   The device manufacturing method according to claim 42, wherein the phase is used to control one direction of the relative position, the one direction corresponding to a direction along which the optical properties of the spatially periodical alignment structure vary periodically, said range of relative positions among which the amplitude is maximized being distributed in a single further direction transverse to said direction.

45.   (*Original*)   The device manufacturing method according to claim 42, wherein the phase is used to control a first direction of the relative position, a second direction of the relative position being controlled using a further phase determined from a phase grating alignment measurement using a further alignment structure with optical properties that vary spatially periodically along the second direction,

further comprising determining information about amplitudes of periodic variations of the intensity of measurement light from the alignment structure and the further alignment structure as a function of the relative position of the substrate table and the patterning structure in directions transverse to the first and second direction respectively,

said searching including searching for a position that maximizes the amplitudes determined for the alignment structure and the further alignment structure in the directions transverse to the first and second direction respectively.

46.   (*Original*)   The device manufacturing method according to claim 42, wherein the alignment structure is spatially periodically variable along a single periodic direction, the phase being used to control one direction of the relative position, the one direction corresponding to said single periodic direction, the range of successive relative positions among which the amplitude is maximized being distributed in two directions on the substrate.

47.   (*Original*)   The device manufacturing method according to claim 42, comprising measuring the intensity information of measurement light diffracted by the alignment structure in selected directions corresponding to a pair of opposite non-zero orders of diffraction.

48. (*Original*)   The device manufacturing method according to claim 42, wherein the optics comprises an imaging element for creating an imaging relationship between the substrate and a reference structure with spatially periodically varying optical properties, the reference structure having a period that corresponds to the period of the alignment structure when imaged onto the reference structure, the method comprising measuring the intensity information from measurement light that has been reflected and/or transmitted by both the reference structure and the alignment structure.

49. (*Withdrawn*)   An alignment structure comprising at least one phase grating mark having a plurality of adjacent lines and spaces with a predetermined periodicity,

wherein the alignment structure comprises a non-periodic feature located between two parts of the alignment structure that have predetermined periodicities along a line.

50. (*Withdrawn*)   The alignment structure according to claim 49, in which the non-periodic feature includes a change of the width of one of the lines or spaces of the alignment structure between the two parts of the alignment structure.

51. (*Withdrawn*)   The alignment structure according to claim 49, wherein the non-periodic feature comprises a transition from a first part of the alignment structure having a first periodicity to a second part of the alignment structure having a second periodicity,

wherein the first periodicity is less than the second periodicity.

52. (*Withdrawn*)   The alignment structure according to claim 51, wherein the first periodicity is less than the periodicity of a reference grating, and wherein the second periodicity is greater than the periodicity of the reference grating.

53.   (*Withdrawn*)   The alignment structure according to claim 49, wherein the alignment structure comprises a position-dependent period change expressible as

$$\Delta(x) = \frac{\cos\left(\frac{2\pi}{L}x\right) - 1}{x}$$

in which $\Delta(x)$ denotes the position-dependent period change, x denotes a position along the alignment structure, and L denotes a length of the alignment structure over which the phase varies.

54.   (*Withdrawn*)   The alignment structure according to claim 49, in which the non-periodic feature includes a transition from a first part of the alignment structure to a second part of the alignment structure, the first part having a periodicity of X microns and the second part having a periodicity of X/n microns, X being a positive nonzero number and n being a positive nonzero integer.

55.   (*Withdrawn*)   The alignment structure according to claim 49, in which the non-periodic feature includes a the transition from a first part of the alignment structure to a second part of the alignment structure, the first part having a first duty cycle value of the lines and spaces and the second part having a second duty cycle value of the lines and spaces different than the first duty cycle value.

56.   (*Withdrawn*)   A substrate including an alignment structure comprising at least one phase grating mark having a plurality of adjacent lines and spaces with a predetermined periodicity,

wherein the alignment structure comprises a non-periodic feature located between two parts of the alignment structure that have predetermined periodicities along a line.